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HARNESSING TECHNOLOGY: EVALUATING MOBILE PHONE TEXT MESSAGING AS A DIABETES SUPPORT INTERVENTION

Katherine E. Mitchell and Samuel J. Thompson, PhD

[1]Medical Unit, Diana Princess of Wales Hospital, Grimsby, United Kingdom

[2]Department of Public Health, University of Chester, United Kingdom

Abstract: Diabetes Mellitus (DM) is a pervasive and enduring global health concern, contributing significantly to mortality, morbidity, and substantial healthcare resource utilization (World Health Organization, 2020). The escalating incidence of DM poses unprecedented challenges to healthcare systems worldwide, necessitating a strategic focus on enhancing diabetes care and patient outcomes through self-management interventions (Lin et al., 2020; Kitsiou et al., 2017; Powers et al., 2017). This paper explores the chronic nature of DM, arising from pancreatic insufficiency or impaired insulin utilization, leading to persistent hyperglycemia and consequential organ damage. The repercussions include vision loss (retinopathy), renal failure (neuropathy), and neurological disorders (Liu et al., 2020; Lotfy et al., 2017).

To address the burgeoning prevalence and impact of DM, it is imperative for healthcare providers and policymakers to adopt effective self-management interventions. These interventions play a pivotal role in mitigating the enduring effects of DM, thereby improving patient outcomes and alleviating the strain on healthcare systems. The objective of this paper is to critically examine the current landscape of diabetes care and the role of self-management interventions in optimizing patient well-being.

The relentless rise in DM cases underscores the urgency for a comprehensive approach to diabetes management. The paper reviews existing literature on the subject, synthesizing evidence from studies conducted by Lin et al. (2020), Kitsiou et al. (2017), Powers et al. (2017), Liu et al. (2020), Lotfy et al. (2017), and others. By analyzing these studies, the paper aims to identify key trends, challenges, and opportunities in diabetes care, with a specific focus on the impact of self-management interventions.

Keywords: Diabetes Mellitus, Self-management interventions, Chronic disease, Healthcare, Patient outcomes.

Introduction

Diabetes Mellitus (DM) is a known long-lasting disease that badly affect lots of individuals globally, which result to significant mortality, morbidity and excessive utilization of resources in health care facilities (WHO-World Health Organization, 2020). This disease condition has continuously placed unmatched pressure on the health care schemes globally (Lin et al, 2020; Kitsiou, Pare, Jaana, & Gerber, 2017). The incessant and predictable increase in the incidence of DM in addition to the expenses resulting from the lasting effects of this disease condition, have drawn the mind-sets of the health care providers and the policy makers on focussing on how best to enhance diabetes care and patient's outcomes, utilising self- management interventions (Powers et al., 2017).

DM is a known chronic ailment that occurs as a result of the inability of the pancreas to produce adequate insulin or when the body finds it difficult utilising effectively, the insulin produced (American Diabetes Association-ADA, 2010). The chronic increase in the blood sugar level which results from uncontrolled diabetes leads to lasting damage effect and the inability of some vital organs in the body to function. This effect includes possible loss of vision (retinopathy), renal failure (neuropathy), and neuron disorder (neuropathy) (Liu et al, 2020; Lotfy, Adeghate, Kalasz, Singh, & Adeghate, 2017). This disease condition has been among the most common long-lasting diseases experienced all over the world and has gradually remained on the increase in terms of prevalence and significance (Khan et al, 2020).

DM can be viewed as a group of metabolic diseases traditionally associated with high levels of glucose in the blood that causes problems in insulin production and insulin use, or both (ADA, 2010). Recently, WHO announced the gradual rise in the prevalence of DM over the past years, around the world (WHO, 2019). The International Diabetes Federation (IDF) global estimate showed that approximately 415 million adults were living with diabetes mellitus in 2015 with a projected increase of about 642 million by the year 2040 (Ogurtsova et al., 2017). Developing and under developed countries are the hardest hit by the burden from the disease condition, as approximately 80% of DM cases occur in these nations (Zhang et al., 2010).

It has been stated from researches that 14.2 million adults in Africa between the age range of 20 and 79 years are diabetic, and are estimated to rise to 34.2 million by 2040 (Mbanya, Motala, Sobngwi, Assah, & Enoru, 2010). Notwithstanding, the high prevalence of DM recorded about 193 million individuals representing that up to half of the population living with DM are unaware of their condition (Fan, 2017). Continentally, the approximated prevalence of DM is in Africa was 3.8%, 10.7% in the North and Middle

East of Africa, 7.3% in Europe, 11.5% in the Caribbean and Northern America, 9.6% in the Central and Southern part of America, 9.1% in the South-eastern part of Asia, and 8.8% in the Western Pacific (Fan, 2017). High populated Countries such as the United states, China, and India, have continually being on the increase in terms of prevalence of individuals living with DM (WHO, 2016). In the United Kingdom (UK), there is a 6% prevalence of DM among individuals between 20 and 79 years (Diabetes UK, 2018). Similarly, the American Diabetes Association (ADA), in 2011 estimated that 25.8 million adults and children were being diagnosed with DM (Control & Prevention, 2011).

The two major types of DM include Type 1 and Type 2 DM (WHO, 2019). Type 1 DM which was once identified as insulin dependent diabetes or juvenile diabetes occurs as a result of the pancreas producing little or no insulin (WHO, 2018). Type 1 DM, according to the WHO is not preventable. Type 2 DM occurs as a result of the body's inability to effectively utilise insulin. It occurs more in adult; however recent studies indicated that Type 2 DM is now also increasingly found amongst children and adolescents (WHO, 2018). Majority of the diabetic patients globally, fall under the category of Type 2 DM. Unlike Type 1 DM, Type 2 DM is highly preventable (WHO, 2019). Other specific types of DM include Gestational DM, which is characterised by increased blood glucose level in pregnancy. The major clinical manifestations of the disease condition include Polyuria (excessive urine), Polydipsia (excessive thirst), Polyphagia (excessive hunger) and weight loss (ADA, 2011). Identification of hyperglycaemia plays an important factor in the diagnosis of DM.

The International Expert Committee suggested that the diagnosis of diabetes be made based on the measurement of the haemoglobin (HbA1c), which in effect signifies the lasting blood glucose concentration (Gillett, 2009). The diagnostic criteria include HbA1c greater than or equal to 6.5% (48mmol/mol), or Fasting plasma glucose

greater than or equal to 7.0mmol/L (126mg/dl) or 2- hr Plasma glucose greater than or equal to 11.1mmol/L (200mg/dl) (Sacks et al., 2011).

Research Methods

Research Aims and objectives

This study was aimed at extracting a pooled estimate of RCTs comparing the effectiveness of Mobile Phone Text Messaging intervention in combination with normal standard care as compared with standard care alone for glycaemic control in diabetes management. This study achieved the principle aim by accomplishing the following objectives;

i. Critically reviewed conducted RCTs that focused on mobile phone text messaging as an intervention for improving healthcare service delivery. ii. Critically reviewed conducted RCTs that focused on mobile phone text messaging as an intervention for improving glycaemic control in diabetes self-management. iii. Analysed the identified and included RCTs using statistical tools such as Standard Deviation, p-values, and confidence interval, to evaluate the intervention under study seeking for evidence of significant effectiveness.

iv. Provided recommendations based on rejected or accepted proposed hypothesis on the best possible approaches towards providing an excellent healthcare service.

Research Question

This review, just like other studies aims to provide an answer to a theoretical question. In meeting up the aim of carrying out a systematic review, the research question to be focussed on, was stated as: Is Mobile Phone Text Messaging Effective as A Supportive Intervention in The Maintenance of Glucose Control?

Research Hypothesis

This study includes both null and alternative hypothesis.

The null hypothesis states that there is no effect or improvement in glucose control amongst diabetic patients that utilised MPTM in comparison to individuals on standard treatment only. Alternative hypothesis states that a significant effect was observed in the glucose control of the patients that used MPTM in comparison to individuals who were on standard treatment only.

Inclusion Criteria

- The criteria include that all studies utilised must be Randomised controlled trials conducted within a time frame of 15 years 01/01/2004 to 01/08/2019. RCTs were used in this study because of its quality in terms of assessing and evaluating therapeutic efficacy, hence right for answering the research question (Stern et al., 2014).
- The participants in this research were diagnosed of Diabetes Mellitus. Type 1 or Type 2 DM to be specific. Studies utilised in this study assessed the effectiveness of MPTM amongst Type1 or Type 2 DM, and the comparator is the use of standard diabetic care only.
- Studies utilising HbA1c in measuring glucose control, prior and after the intervention were included.
- Ages of participants in this study were between 8 and 75 years old.

Exclusion Criteria

They include the following:

- All trials that were not randomized controlled trials.
- Trials conducted on other types of DM except Type 1 or Type 2 DM.

- Trials that compared MPTM with other health conditions apart from Type 1 and 2 DM.
- Studies that compared MPTM and other information technology interventions were not included.
- Studies including pregnant women were not included.

It was vital to exclude such studies as the research design for this review majorly concentrates on comparing the use of MPTM and standard care with the use of standard care only. Incomplete and ongoing studies were excluded from this review too.

Studies Included

The randomized controlled trial studies utilized in this review were conducted in, New Zealand, Egypt, Philippines, South Korea, Scotland, Mexico, and Iran, evaluating the effectiveness of MPTM in combination with standard care, and standard care alone. Comparative RCTs are regarded as gold standard for accessing the effectiveness of public health interventions using systematic review methodology. Seven Randomised Control Trials were selected for this review after a systematic search. Studies selected used literate participants that owned mobile phones, and are able to speak, read, and understand text messages in English Language. These studies used standard care only as a comparator, Studies with clinically certified diabetic patients whose HbA1C levels are greater than 7%. were used. Studies that were accessed to be of low quality were also excluded from this study.

PICO model for defining the clinical research question

PICO model can be defined as a format used for developing an accurate clinical research question before commencing a research (Eriksen & Frandsen 2018; Methley et al, 2014). PICO which means participants, intervention, comparator, and outcome, was used to describe this study as following; **Description of Participants**

The participants in this study were group of individuals, selected randomly from different trials to participate in attesting to the effectiveness of MPTM intervention. The individuals involved were all diabetic patients undergoing treatment, between 8 and 75 years of age. Both males and female were included, provided they are being diagnosed of DM, with Hba1c > 7%.

Type of intervention

Intervention in research is referred as a treatment regimen allocated to research participants with the aim of evaluating and assessing the effectiveness of a particular treatment/intervention (Eriksen, 2020; Higgins & Green, 2011). The intervention in focus for this systematic review was Mobile Phone Text Messaging Plus Standard Care. **Comparator**

In this study, the comparator is the use of standard care only. Amongst various studies utilised in this review, the comparators were stated as Usual care, Standard Care or Conventional care, but for the interest of uniformity in this review the comparator will be addressed as Standard Care (SC). However, they all have the same meaning. Standard Care includes diabetic medications, glucose monitoring, medical advice and follow up appointments.

Evaluation of outcome

The primary outcome in this review, which is of great interest to the reviewer is an improved glucose control., which will be measured by the glycosylated haemoglobin (HbA1C). The HbA1c test signifies the average blood glucose level of an individual (ADA, 2014). However secondary outcomes include those outcome measures that will be useful to those in authority such as the decision and policy makers. The secondary outcomes could include:

cost effectiveness of the intervention, health related quality of life, perceived social support, improved self-care behaviours and improved self-efficacy. This study however focussed on the Primary Outcome. **Search strategy**

An effective search strategy is very vital, because it helps in gathering appropriate articles needed to meet with the inclusion criteria (Stern et al., 2014; Wager & Wiffen, 2011), therefore a systematic and detailed search is essential. A well conducted search strategy gives a brief summary of the process, on how trials useful in a systematic review are selected (Parahoo, 2014). Boolean operators like "AND", "OR" were utilized in identifying distinct studies needed in a review.

Three major factors were employed in this review's search strategy, which are

- Using a reproducible method,
- Being specific in selecting the appropriate article required to answer the study question and
- avoiding time wastage and Sensitivity in terms of data protection. The manual and electronic methods were adopted in identifying articles needed for the review (Parahoo, 2014).

A precise database known as the Cochrane database of Systematic Review (CDSR) was searched before conducting this systematic review, for RCTS and systematic reviews evaluating the effectiveness of MPTM towards maintaining glucose control amongst patients with DM. Electronic search was also thoroughly conducted in other useful databases which include PubMed, CINAHL, Clinical Trials.Gov, Medline, Cochrane Library, Embase and Database of Abstracts of Reviews of Effect (DARE). Additionally, databases such as BIOSIS was used in sourcing for articles shown in conferences. The Latin American and Caribbean Health Sciences (LILACS) was also included in the search for studies that met the criteria needed.

Keywords such as "Text messaging", "SMS", and "diabetes mellitus", "Mobile Phone text messaging and glucose control" were used while conducting the search strategy. The summary of search strategy was outlined in Table 4.1 below.

Table 4.1 Preliminary Study Selection

Database searched	Search Terms	Date Assessed	Number of studies identified by liberal search of database	Time period/Language restriction.
CINAHL	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	1	01/01/2004-01/01/2019 No Language restriction
PubMed	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND	10/09/2019	72	01/01/2004-01/01/2019 No Language restriction

	"Randomised Controlled Trials"			
Medline	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	3	01/01/2004-01/01/2019 No Language restriction
Cochrane Central Register of Controlled Trials	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	70	01/01/2004-01/01/2019 No Language restriction
LILACS	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	2	01/01/2004-01/01/2019 No Language restriction
Health Technology Assessment	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	100	01/01/2004-01/01/2019 No Language restriction
Web of Science Core Collection	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	3	01/01/2004-01/01/2019 No Language restriction
Ongoing Studies	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	3	01/01/2004-01/01/2019 No Language restriction
Other Sources	"Mobile Phone Text Messaging" AND "Diabetes Mellitus" AND "Randomised Controlled Trials	10/09/2019	3	01/01/2004-01/01/2019 No Language restriction
Total			257	

Study selection process

To reduce chances of selection bias, this review adopted the guidelines stated by the Centre for Review and Dissemination (2009) and in combination with the guidelines set by Cochrane Handbook of Systematic Review (Higgins & Green, 2011). The selection criteria for this systematic review was outlined under the eligibility criteria. The systematic selection process first involved the electronic search for articles on the database with consistency in view of the research question and the eligibility criteria. Titles, abstracts and reference were evaluated towards selecting articles that conform with the research question. RCTTs that were not consistent in answering the research question were excluded from the review, following a comprehensive systematic screening. Studies that met the inclusion criteria were selected. Full text of the articles was recovered and used for the systematic selection process and future analysis. Methodological quality of the potentially included studies were accessed using the standards set by Consolidated Standard of Reporting Trials (CONSORT) statement of checklist also known as Cochrane collaboration risk of bias tool (Schulz, Altman, & Moher, 2010). This ensured that articles accessed as low quality of methodology were not included in the review. The preliminary study selection process for this systematic is presented in Figure 4.1 using a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for systematic review.

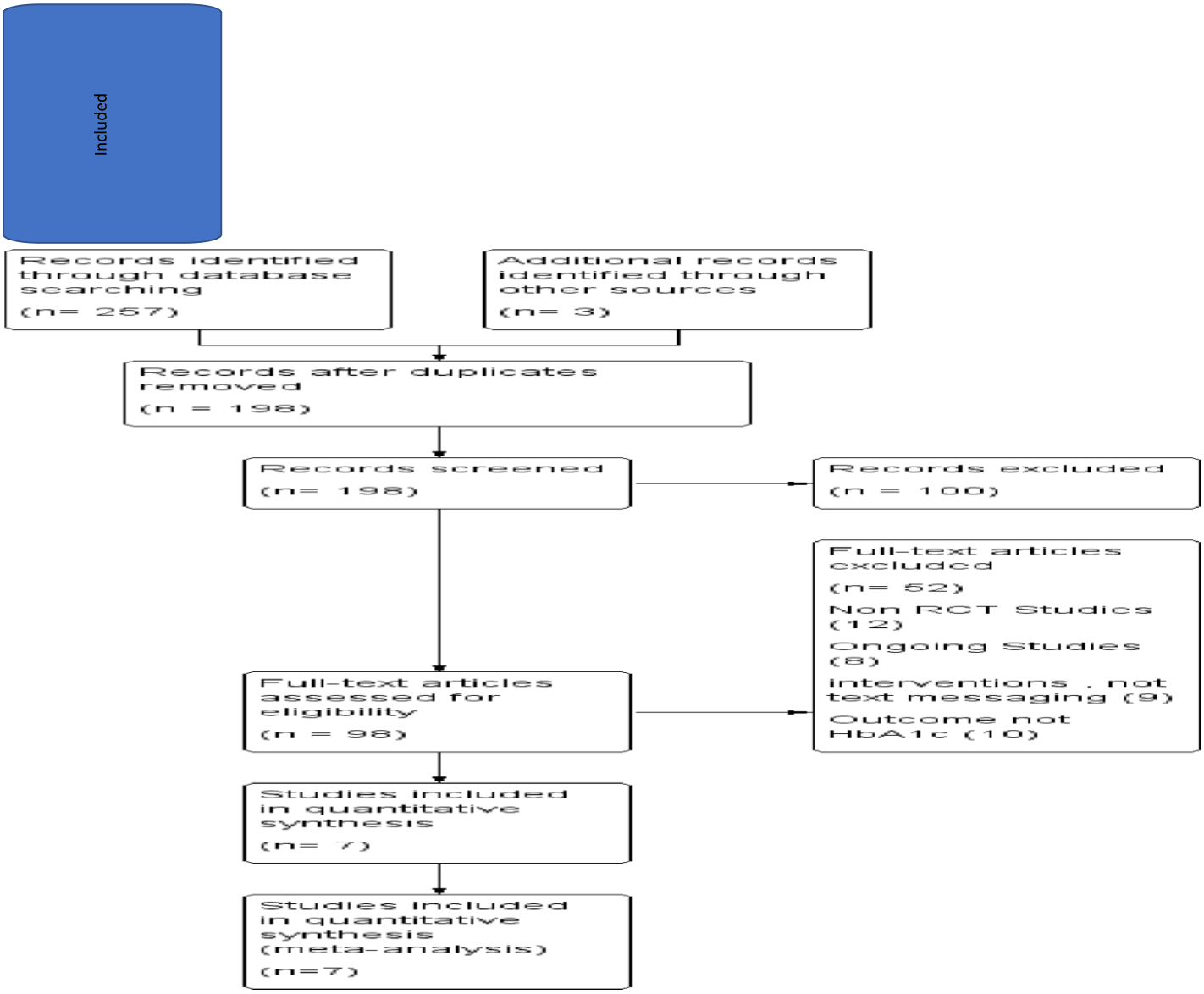


Figure 4.1 Prisma Table (Moher et al., 2009).

Table 4. 2: Features of the included studies

Study	Population	Intervention/Duration	Comparator	Outcome
SMS education for the promotion of Diabetes Self- Management in low- & Middle-Income Countries: A randomized controlled trial in Egypt. *Abaza and Marschollek, 2017.*	90 Type 2 DM patients in an Egyptian hospital aged 12-69 years.	Daily text messages and weekly reminders for Diabetes care plus standard care for 12 weeks	Standard Care	Glycosylated Haemoglobin
Effectiveness of Text Message Based, Diabetes self-management support programme (SMS4BG): randomised controlled trial. Dobson et al., 2018	366 Type 1 or Type 2 DM patients from New Zealand. Aged 16 years and above	Tailored package of text messages for diabetes selfmanagement plus standard care for 9 months	Standard Care	Glycosylated Haemoglobin
An mHealth SMS-Based Intervention Improves Glycaemic Control in Hispanics with Type 2 Diabetes. *Fortmann et al., 2017*	126 Type 2 DM Hispanic patients in San Diego. Aged 16-75 years.	Dulce digital text messages plus Standard care for over 6 months	Standard Care	Glycosylated Haemoglobin
A Randomised Controlled Trial of Sweet Talk, A Text Messaging System to Support Young People with Diabetes. Franklin et al., 2006.	126 type 1 DM patients in Scotland. Aged 8-18 years	Conventional therapy plus Sweet Talk Messages for 12 months.	Conventional therapy	Glycosylated Haemoglobin

A Randomised Controlled Trial of a Nurse Short Message Service by Cellular Phone for people with Diabetes. *Kim, 2006*	60 Type 2 DM patients in South Korea. Aged 18-50 years	Internet based intervention using short message service (SMS) plus Standard Care for 12 weeks	Standard Care	Glycosylated Haemoglobin
Use of Short Message Services (SMS) for the Management of Type 2 Diabetes Mellitus: A Randomised Controlled Trial. *Tamban et al., 2013.*	104 diabetic patients in Philippines. Aged 19 -50 years	3 SMS per week plus standard care for 6 months	Standard Care	Glycosylated Haemoglobin

Quality assessment

It is important that quality of included studies is assessed when conducting a systematic review, because it determines if and to what extent, the results from studies were unduly influenced by the study designs selected (McDonagh, Peterson, Raina, Chang, & Shekelle, 2013; Smith & Noble, 2014). This was achieved by recording the strength and weakness of all included studies. Therefore, it is essential to adopt the use of Critical Appraisal Skill Program (CASP) tool in minimising bias. This tool is essential in conducting an appropriate methodological quality assessment of included studies (Voss & Rehfuess, 2013). This study used CASP tools in evaluating the methodological quality and standards of RCTS used for this study. While conducting an evaluation and appraisal on the methods, the quality and design included in the review and variations observed in the results are summarised and entered as limitations of the study as recommended (Higgins & Green, 2011). Table 4.3 demonstrates how each study included in the review was assessed utilising CASP tools

Table 4.3: Methodological Quality assessment for included studies using CASP checklist tool for RCTs

CASP Checklist item Yes= Y. Can't tell = C. No= N											
NAME AND YEAR OF STUDY PUBLICATION	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Abaza &Marschollek, 2017	Y	Y	Y	Y	Y	Y	Changes in HbA1c were measured. The difference in the HbA1c concentration between the patients at the intervention and control arm was not significant	P=0.406	Y	Y	Y

Dobson et al., 2018	Y	Y	Y	N	Y	Y	Changes in HbA1c were measured. The reduction in HbA1c was significantly higher in the intervention arm compared to the Control arm.	P=0.007	Y	Y	Y
Fortmann et al., 2017	Y	Y	Y	N	Y	Y	Changes in HbA1c were measured. The reduction in HbA1c was significantly higher in the intervention arm compared to the Control arm	P=0.03	Y	Y	Y
Franklin et al., 2006	Y	Y	Y	C	N	Y	Changes in HbA1c were measured. There was no change in HbA1c between the patients at the intervention and control arm.	P=0.99	Y	Y	Y
Goodarzi et al., 2012	Y	Y	Y	C	Y	Y	Changes in HbA1c were measured. The reduction in HbA1c was significantly higher in the intervention arm compared to the Control arm	P=0.024	Y	Y	Y
Kim, 2006	Y	Y	Y	C	Y	Y	Changes in HbA1c were measured. The reduction in HbA1c was significantly higher in the intervention arm compared to the Control arm	P=0.005	Y	Y	Y
Tamban et al., 2013	Y	Y	Y	Y	Y		Changes in HbA1c were measured. The reduction in HbA1c was significantly higher in the intervention arm compared to the Control arm	P=0.04	Y	Y	Y

Data Extraction

Studies analysed in this review were the selected studies, whose primary outcomes measured differences in haemoglobin concentration (Hba1c) between participants at the intervention and the control arm. Below is a standardized table illustrating the studies utilised in the review. Extraction of significant data that were beneficial for the study was done. Features of the data extracted were the sample size, details of the participants, characteristics of the review and measurement of both the outcome and intervention.

This study stated the various locations at which participants were selected, though it was randomly picked. The participants were from countries of various continents, namely: New Zealand, Egypt, The Philippines, South Korea, Scotland, Mexico, and Iran. The intervention utilised (MPTM) was briefly summarized in the table. The comparison between the MPTM (intervention arm and standard care (control arm) were stated as well. The Rev man software was utilised in entering the extracted data. This was done because Revman software produces a forest and funnel plot utilised in interpreting the results. The metaanalysis was done using the application of a

fixed effect model. Fixed effect model was used because majority of the included studies were quite similar especially in terms of sample size. Standard Deviation was used in measuring the estimated effect., since the measured outcome (HbA1c) was presented in a continuous form. Furthermore, heterogeneity was interpreted in the studies with the value I^2 (Higgins & Green, 2011).

Table 4.4: **Summary of Data Extraction from studies.**

STUDY	ENROLLED PATIENTS	STUDY DURATION	STUDY DESIGN	REGION OF STUDY	AGE OF THE PARTICIPANTS	LOCATION	TYPE OF INTERVENTION	HEALTH STATUS	LOSS TO FOLLW UP	OUTCOME MEASURE
Abaza &Marscholllek, 2017	90	12 Weeks	RCT	Egypt	12-69 years	University of Science and Technology hospital Cairo Egypt.	Daily text messages and weekly reminders for Diabetes care plus standard care	Diabetes Mellitus	17	Glycosylated Haemoglobin
Dobson et al., 2018	366	9 Months	RCT	New Zealand	16 years and above	Primary and Secondary health centres across New Zealand.	Tailored package of text messages for diabetes selfmanagement plus standard care	Type 1 or 2 Diabetes Mellitus	12	Glycosylated Haemoglobin
Fortmann et al., 2017	126	Over 6 Months	RCT	San Diego	16-75 years	Federal health Centre, San Diego	Dulce digital text messages plus Standard care	Type 2 Diabetes Mellitus	17	Glycosylated Haemoglobin
Franklin et al., 2006	126	12 Months	RCT	Scotland	8-18 years	Tayside Clinic Scotland	Conventional therapy plus	Type 1 Diabetes Mellitus	67	Glycosylated Haemoglobin

							Sweet Talk Messages			

Goodarzi et al., 2012	100	12 Weeks	RCT	Iran	Above 30 years	Karaj Diabetes Association, Iran.	Four text messages weekly plus standard care	Type 2 Diabetes Mellitus	19	Glycosylated Haemoglobin
Kim, 2006	60	12 Weeks	RCT	South Korea	18-50 9years	Endocrinology department in a tertiary care hospital, South Korea	Internet based intervention using short message service (SMS) plus Standard Care	Type 2 Diabetes Mellitus	9	Glycosylated Haemoglobin
Tamban et al., 2013.	104	6 Months	RCT	The Philippines	19-50	University of the Philippines General Hospital	3 SMS per week plus standard care	Diabetes Mellitus	22	Glycosylated Haemoglobin

T**able 4.5: Study outcome data**

STUDY	NOS OF PATIENTS THAT COMPLETED THE STUDY	INTERVENTION/CONTROL	STUDY DESIGN	OUTCOME (SD MEAN DIFFERENCE/95% CI)
Abaza &Marschollek, 2017	73	Daily text messages and weekly reminders for Diabetes care plus standard care / Standard Care	RCT	HbA1C -0.10[-1.11, 0.91]
Dobson et al., 2018	354	Tailored package of text messages for diabetes selfmanagement plus standard care/ Standard Care	RCT	HbA1C -4.90[-8.22, -1.58]
Fortmann et al., 2017	109	Dulce digital text messages plus Standard care/ Standard Care	RCT	HbA1C -0.90[-1.51, -0.29]
Franklin et al., 2006.	59	Conventional therapy plus Sweet Talk Messages/Conventional Therapy	RCT	HbA1c -0.20[-1.07, 0.67]

Goodarzi et al., 2012	81	Four text messages weekly plus standard care/ Standard Care	RCT	HbA1C -0.50[-1.01, 0.01]
Kim, 2006	51	Internet based intervention using short message service (SMS) plus Standard Care/ Standard Care	RCT	HbA1C -0.80[-1.32, -0.28]
Tamban et al., 2013	82	3 SMS per week plus standard care/ Standard Care	RCT	HbA1C -0.30[-0.69, 0.09]

Data Analysis

Data analysis during systematic review involves the collection, summary, and combination of all included studies, to make informed decision based on their findings. (Higgins & Green, 2011). Data were analysed using both descriptive and narrative analysis, to synthesise data into an important piece of information. The analysis started with a descriptive summary of the included studies (Table 4.2), data extracted were inputted into a Review manager (Revman) 5.3 software as recommended by the Cochrane collaboration, as an essential tool for analysing extracted result during a systematic review for the effectiveness of public health intervention. This software was developed in consultation with Cochrane methodologist and reviewers to support standards and guidelines for systematic reviews. Therefore, it is regarded as a gold standard for analysis of data for effectiveness of a public health intervention (Higgins & Green, 2011).

Data inputted into the Revman software were automatically synthesized into graphical form with statistical tools which include *Chi-square*, *P-value* and I^2. These tools were applied to test the significance of the intervention as stated by the Cochrane intervention (Higgins & Green, 2011). These graphical representations were in the form of forest and funnel plots. Incomplete or missing data were taken into consideration when conducting this systematic review. This was to prevent manipulation of results which in itself is a bias. The problems associated with incomplete or missing data were solved by ensuring that only studies with complete data for each analysis were used for the analysis of outcomes of interest.

Assessment of Heterogeneity

While conducting this review, the assessment of heterogeneity was conducted on the studies included. All the studies selected in this review were thoroughly assessed of heterogeneity.Heterogeneity can be referred to as disimilarities in the articles utilised in the review. These differences could be in the form of statistical, clinical or methodological variation (Centre for Reviews and Dissemination, 2009; Furlan, Pennick, Bombardier, & van Tulder, 2009; Higgins, 2013). Methodological heterogeneity deals with variations in the methodologies utilised in the independent studies which includes allocation concealment, Blinding and disimilarities witnessed in the definition and assessment of outcomes. Statistical Heterogeneiity on the other hand recommends that the incuded studies are likely to lack the ability to estimate same quantity, though ststistical heterogeneity is known to evolve from methodological variety, Nevertheless, the above ststement fails to conclude on the ideology of occurrence of variation on the true intervention effect. Finally, Clinical Variations, are intervention effects arising as a result of variations in the study settings, patient's features and the value of the intervention utilised (Centre for Reviews and Dissemination, 2009; Tacconelli, 2010). The Revman software was used to test for heterogeneity during data analysis and the reuslts were interpreted in the result section.

Results Of The Research

This Review evaluated 257 published articles in assessing the effectiveness of MPTM on glucose control. This was achieved through a comprehensive search carried out in various electronic data bases as stated in Table

4.1. Following the exclusion of certain studies, due to duplication and inability in meeting up the criteria designed for the included studies, 10 studies met the standards for the inclusion criteria, though only seven papers were utilised as three studies were later excluded as a result of missing data. This systematic review and meta-analysis were then conducted using seven studies. PRISMA flow chart was used to illustrate the process at which eligible studies were selected (see fig 4.1) Characteristics of the seven included studies were illustrated in table 4.2. The dates, at which the included studies were published ranged from 2004 to 2019. A total of 809 patients diagnosed with either Type1 or Type 2 Dm were included in the studies, though majority were Type 2 DM patients. This review had 407 patients in the experimental group and 402 at the intervention arm.

The participants included in the study ranged between the ages of 8 and 75 years. Both male and female were included. Studies were carried out in different regions of the world, including Africa, Asia, Southern America and Europe. Out of the seven included studies, three studies had a study duration of 12 weeks(Abaza & Marschollek, 2017; Goodarzi et al., 2012; Kim, 2007), whiles the remaining three studies had a duration of 9, 12 and 6 months respectively (Dobson et al., 2018; Franklin, Waller, Pagliari, & Greene, 2006; Tamban et al., 2014), except one study that was not very specific, however, the author stated the study duration as over 6 months (Philis-Tsimikas, Fortmann, Garcia, Ruiz, & Schultz, 2016). Seven studies utilised SMS as an interactive approach in terms of sending and receiving information to and from the patients. However, one of the studies utilised websites as well as SMS in sending and receiving data from participants (Kim, 2007). Two studies reported insignificant differences in HbA1c between the control and intervention arm (Abaza & Marschollek, 2017; Franklin et al., 2006). Nevertheless, none of the studies reported a significant difference in HbA1c, favouring the control group.

Based on quality assessment, two of the published included studies were at high risk for internal bias (Dobson et al., 2018; Philis-Tsimikas et al., 2016), however internal validity is acceptable in circumstances of low to moderate risk. Moreover, a study by Wood et al., (2017) sated that, in terms of assessing outcomes such as Hba1c, absence of blinding has little or no chances of influencing the outcome.

Standard deviation was used in measuring the estimated effect, assessing the HbA1c concentration (primary outcome). As a continuous data, the analysis was done at 95% confidence interval. The seven included studies in the review, all had HbA1c as their primary outcome. The Meta-analysis was conducted on all the included studies, with the aim of producing a pooled effect. During the assessment of Heterogeneity, the Chi square test was (Chi^2=11.67). I-squared was less than 50% (I^2 = 49%), indicating less heterogeneity. While comparing The Mean Differences between the control and intervention group. An overall value of Mean Difference (MD) generated was stated as 95% CI =-0.53 [-0.75, -0.30]. The test for overall effect was significant, which was stated as

(Z=4.50; P<0.00001). Well detailed meta-analysis including the funnel and forest plot were displayed in Figures 5.11 and 5.12.

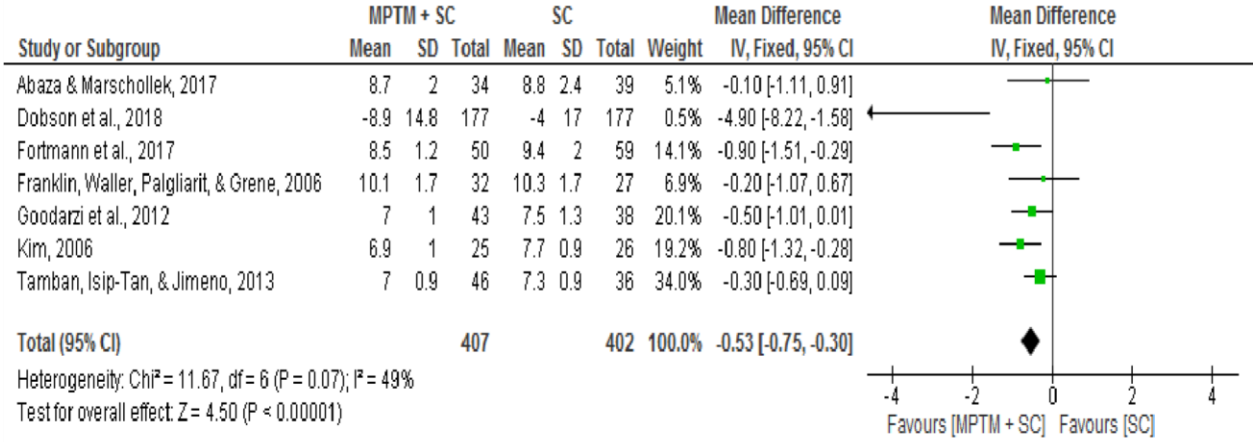


Figure 5.11: Forest Plot comparing MPTM +SC with SC and HbA1c as primary outcome.

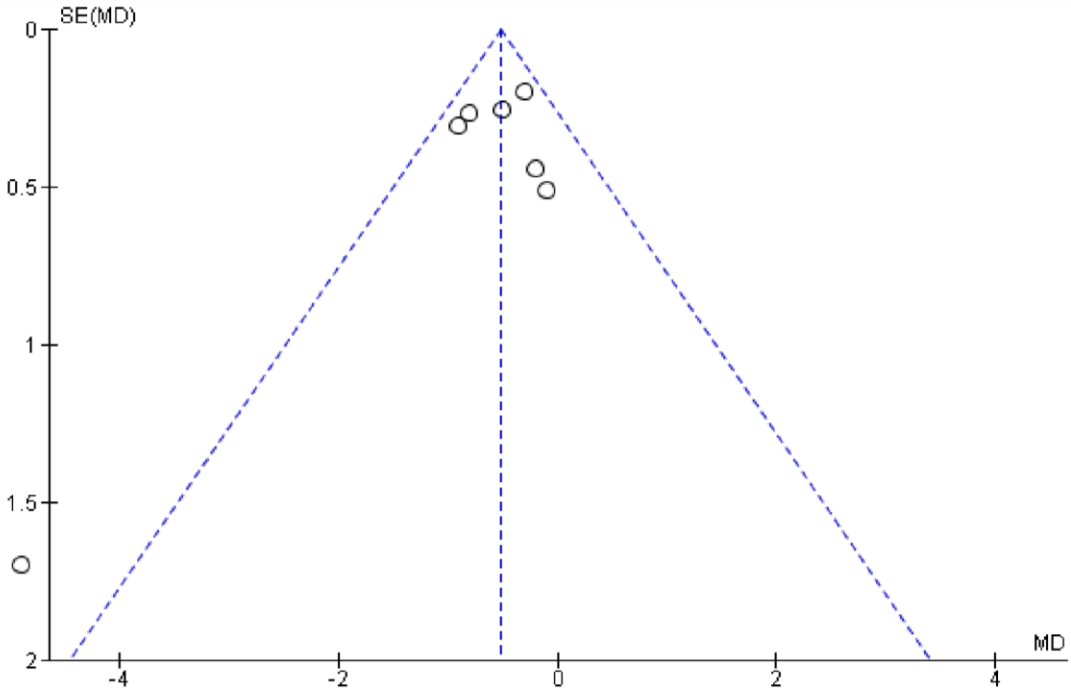


Figure 5.12: Funnel Plot comparing MPTM +SC with SC and HbA1c as primary outcome.

Based on the illustration of the funnel plot demonstrated in figure 5.12., All the studies displayed on both sides of the plots were distributed symmetrically and captured within the precision of pooled effect however it was observed that the study by Dobson et al., 2018 laid outside the symmetry of precision as it contributed the lowest weight to the Meta-analysis.

A second meta-analysis was also conducted excluding studies with large sample size. A total of 407 participants were recorded with 200 at the experimental group and 207 at the control group. The second analysis reported the

following results, which was stated as MD = 95% CI =-0.50 [-0.73, -0.28]. and Chi^2= 4.98, I^2= 0%, Z= 4.31 at P < 0.00001. This in essence indicates that the heterogeneity was likely high in the first meta-analysis as a result of high variation of sample size presented in study by Dobson et al., 2018. Due to the limited available studies that met the inclusion criteria, the work by Dobson et al was also utilised in carrying out the investigation for this review not minding the high sample size which was different from the rest of the studies.

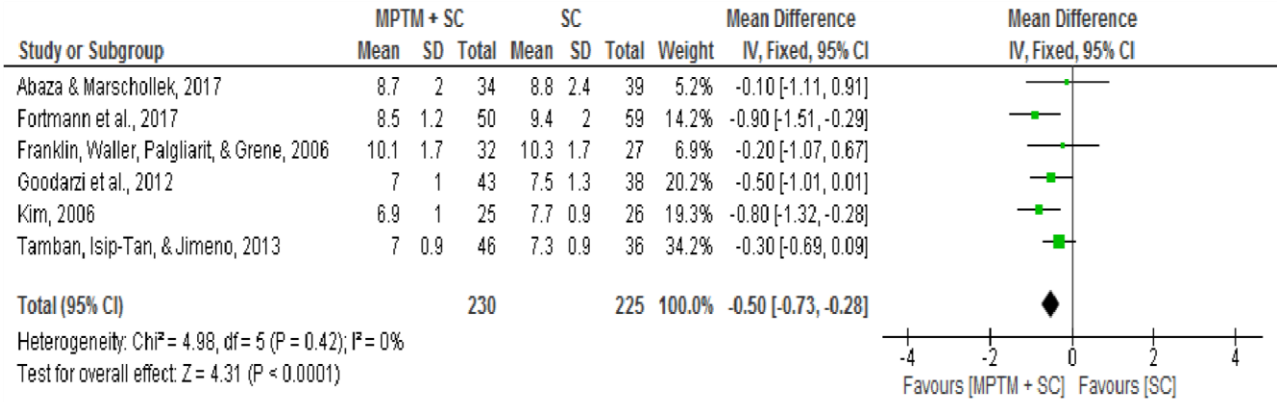


Figure 5.13: Forest plot comparing MPTM +SC with SC and HbA1c as primary outcome. (this diagram excludes the study with large sample size.

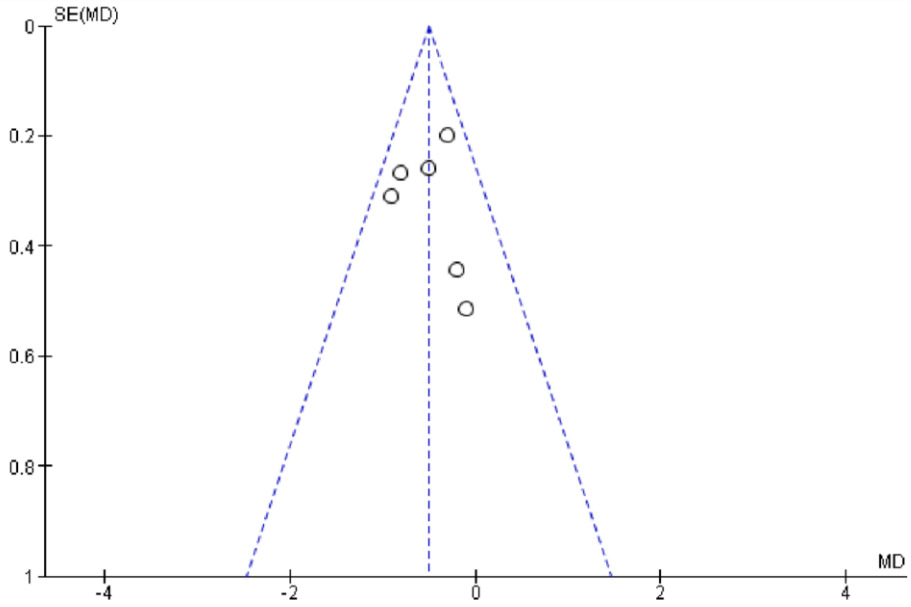
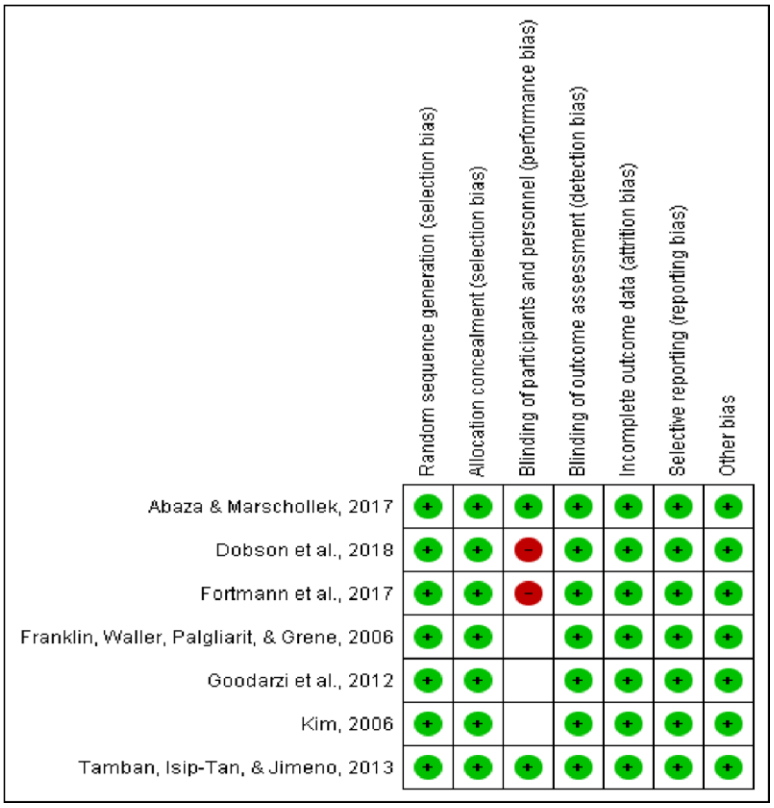


Figure 5.14: Funnel Plot comparing MPTM +SC with SC and HbA1c as primary outcome. (this diagram excludes the study with large sample size **Risk of bias of the selected studies**

The included studies for this systematic review investigated for risk of bias using the Revman as recommended by the Cochrane collaboration. The assessment of risk of bias was conducted using descriptive analysis. The summary of the occurrence of all types of bias across the included studies are represented below (Figure 5.2) as produced by Revman software. The risk of bias analysis was based on the reviewer's judgement on what was reported on the included studies. Based on the summary of risk of bias assessment, it was indicated in the graph,

that blinding of personnel and participants had the greatest risk as two studies were indicated to be at high risk(Dobson et al., 2018; Philis-Tsimikas, Fortmann, Garcia, Ruiz, & Schultz, 2016), while 3 studies were unclear as the reviewer failed to mention whether blinding of participants and personnel were actually carried out during the course of the study(V. L. Franklin et al., 2006; Goodarzi et al., 2012; Kim, 2007). However, all the include studies posed low risk to selection, detection, attrition and reporting bias. As this systematic review included only RCTs, it was essential that all studies included were first judged for random sequence generation before other bias domains were investigated. There was no other type of bias detected in any of the included studies.



***Fi*gure 5. 1** The risk of bias summary of each study included in this systematic review based on the reviewer's judgement for each bias domain.

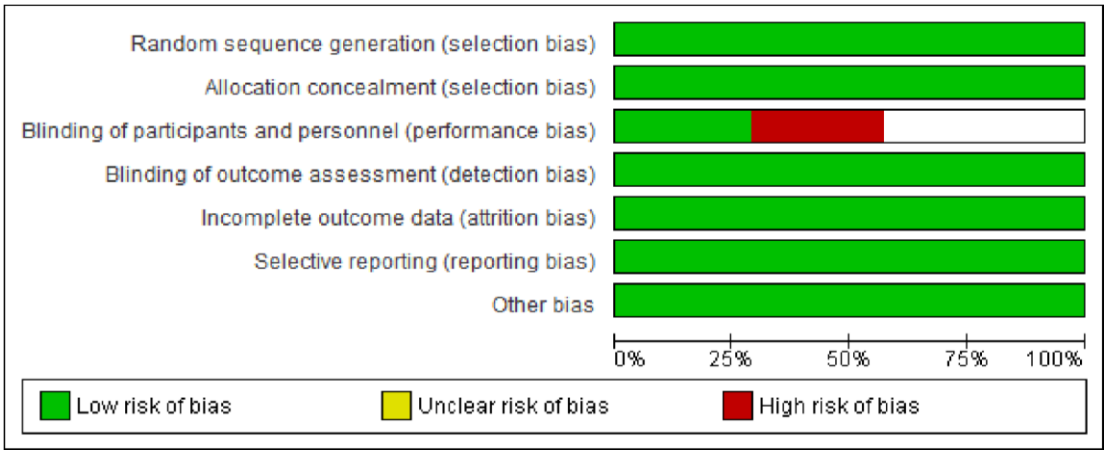


Figure 5. 2 The risk of bias graph. The risk of each bias domain is presented in percentage based on the reviewer's judgement, across all included studies.

Findings of Meta-Analysis

The first Meta-analysis involved all the included studies, while the second meta- analysis excluded a study with large sample size. The results obtained from the Meta-analysis were illustrated in the funnel plots and forest plots. Heterogeneity and P value were utilized in interpreting the results in the plot. The result from the Metaanalysis conducted on the studies indicated that Mobile Phone Text Messaging was effective in the maintenance of glucose control. A total of 809 participants were generated as the sample size from the pooled effect and were randomised in to MPTM +SC group and SC group. The Mean difference (MD) of the analysis indicated that the proposed intervention (MPTM + SC) was effective in the Maintenance of glucose control amongst Diabetic patients (MD=-0.53, 95% CI= -0.75, -0.30, P < 0.00001). A statically significant result was generated from the overall pooled effect, with a p value less than 0.05 and a confidence interval with narrow width. Hence disproving the null hypothesis with a prediction of the results, occurring by chance. This indicates the effectiveness of the intervention in reducing the Hba1c concentration amongst diabetic patients.

All the studies with the exception of two (Abaza & Marschollek, 2017; Franklin et al., 2006) did not cross the line of no effect. Nevertheless, the 95% CI was continuously at the left side, hence favouring the intervention. It was indicated in the result, that the two studies that crossed the line of no effect individually also had a mean difference less than one, thereby favouring the intervention. However, both studies were statically insignificant with P values greater than 0.05. Irrespective of the statically insignificance of the studies, it was observed in the study by Franklin et al., that though there was no decrease in the Hba1C between the intervention and control group. Patients verbalised that the intervention improved their self-management skills and demonstrated their interest to continue with the intervention. Also, the study by Abaza and colleagues indicated that majority of the participants at the intervention arm had decreased HbaIc. Due to the statically insignificance of the result, the effectiveness of the study will be termed to have occurred by chance.

The illustrated funnel plot generated from the seven studies indicated absence of publication bias. The utilised studies were distributed symmetrically around the pooled MD. The statically significance stated as P <0.00001, supports the alternate hypothesis that proposed the effectiveness of MPTM in the maintenance of glucose control amongst DM patients. This in essence states that the intervention helped in reducing the Hba1c level, which in effect improved the glucose level of the patients. Heterogeneity which was stated as 1^2 =49%, was suspected be that high as a result of higher sample size in the works of Dobson et al., when compared to the rest of the utilised studies.

Heterogeneity was therefore re assessed in a second meta-analysis by excluding the study of Dobson which had higher sample size, than the rest of the studies. The result from the second meta-analysis indicated also statically significant P values with a 0 percent heterogeneity, as against the initial 49% heterogeneity. The result was stated as (MD= -0.50, 95% CI= (-0.73, -0.28), P < 0.0001). The funnel plot indicated symmetrical distribution of studies around the pooled effect hence disproving the chances of publication bias.

Discussion

This systematic review focused on the work done to assist diabetic patients to manage their disease condition, improve behavioural and health outcomes using Mobile Phone Text Messaging (MPTM) intervention. Disease conditions such as diabetes requires the maintenance blood sugar levels and other related clinical and physiological measurements to tolerable levels through monitoring and management with consistent self-care

routines (Jarvis, Skinner, Carey, & Davies, 2010). It was vital to note the increased use of mobile phone interventions in healthcare service delivery due to the fact that majority of individuals own a phone. As stated in the literature review, several studies have evaluated its impact as an intervention to improve various treatment regimens and management in healthcare delivery. These studies have demonstrated many positive trends, though few significant findings were reported.

Mobile phones as a management tool was used to enable an effective and timely flow of accurate and precise short information flow between the patients and the healthcare service providers. In some of the included studies, text messaging was used to facilitate management advice and support in between healthcare centre appointments. While in other studies, text messaging was used to deliver regular and timely alerts, and reminders to achieve the desired objective. All the included studies measured HbA1c before and after intervention and showed a significant decrease in HbA1c values. Results of this systematic review showed that educational interventions through the provision of personalized advice and support, regular and timely alerts, and reminders delivered through mobile phones may assist to manage diabetes and other related clinical and physiological complications thereby improve health outcomes. Reports from different studies suggested that that as low as 1% reduction in glycosylated haemoglobin can result in 37 % reduction in risk of mortality as well as micro vascular disorders (Stratton et al., 2000). This review therefore highlighted the positive and significant evidence for rendering healthcare interventions that concentrated on managing diabetes through mobile phone text messaging service. The results of the review in line with various analysed literature (as stated on the literature review) indicated that interventions obtained through text messaging were very beneficial in terms of positively influencing the health outcome of patients.

Summary of Effectiveness

A study is said to be statistically significant, when the P value is less than 0.05, with a 95% confidence interval and a narrow width that fails to cross the line of no effect (Ellis & Steyn, 2003). The meta-analysis conducted proves the evidence that MPTM is statically significant in the maintenance of glucose control. The interpretation is that Mobile phone text messaging in addition to standard care is more effective in reducing the Hba1c levels among diabetic patients compared to standard diabetic care only. Based on the generated result in this review, results of certain studies that are in consistent with this review's intervention were compared below. A systematic review carried out by Saffari and colleagues in 2014, evaluated the effectiveness of text messaged based programme in maintaining glucose control amongst type 2 diabetic patients. The intervention utilised in this study was text message programme plus standard care. The average age of the participants in the study was 53 years .10 studies were analysed in this review. Participants at the intervention arm received text messages created in a tailored package called Diabetes Self-Management education. The result of the study in consistence with this review indicated a significant reduction of HbA1c in the experimental group, when compared to the control group. The overall value was stated as (SMD= -0.595; P<0.001 (Saffari et al., 2014). This indicates that the intervention was effective and statistically significant, as the P value was less than 0.05. The study recorded a total of 50% reduction in HbA1c concentration.

In contrast, a trial by Franklin and colleagues in 2006, included 126 young Type 1 diabetic patients recruited in Scotland between the ages of 8 and 18 years. Patients at the intervention arm received conventional therapy (which for the uniformity of this study was termed Standard Care) plus text messages form sweet talk software for 12 months. The messages contained personalised tailored messages and precise prompts to the patient's gender, age and insulin routine. There was no reduction in the HbA1c concentration at the end of the study. This

was observed in both the intervention and control arm with a p value of 0.99 indicating that the study was not statically significant. However, reports from the study stated that 82% of the participants confirmed that the Sweet talk messaging improved their self-management system and requested to keep receiving the messages (Franklin et al., 2006). However, factors such as sample size and study duration could have affected the significance of the result.

The last study whose result was analysed in comparison with the result of this review was a Meta -analysis conducted by Liang and colleagues in 2010. The study demonstrated also the effect of Mobile phone intervention in the maintenance of glucose control. Unlike this review, Liang's study engaged other forms of mobile technology asides text messaging. Twenty-two trials were utilised in the study with a total of 1657 participants. At the end of the study, it was indicated that mobile phone intervention utilised for diabetes self-management decreased the Hba1c level by 0.5% with a 95% confidence interval (0.3, -0.7) and a P value of 0.02(Liang et al., 2010). The intervention in essence was effective and the p value which was less than 0.05 signified the statistical significance of the study.

In comparison with Standard care alone, it is evident that addition Of MPTM to the standard diabetic care significantly improved the Haemoglobin concentration amongst Type 1 or Type 2 DM patients. The pooled analysis of various studies demonstrated the reduction of HbA1c utilizing the proposed intervention. The result of this review is therefore in consistent with studies in line with the effectiveness of Text messaging in improving health outcome.

Application of evidence and future research

A systematic approach was adopted in selecting and analysing the studies that demonstrated the evidence of the effectiveness of Mobile Phone text messaging in the maintenance of glucose control, though limitations were inevitable. A precise focus was taken in to consideration. Hence, the studies utilised were limited to just studies in which interventions were rendered solely by the means of text messaging. The application of the evidence provided by this systematic review is in ensuring that accurate and timely SMS reminders and updates are incorporated into the currently known diabetes management practices to ensure higher efficiency of selfmanaging diabetes by patients. Only one study, out of all the studies, had a combination of other means of data transmission (internet). Thereby minimising the difficulties that would have been associated with the assessing the effectiveness of text messaging, when combined with other multifaced interventions.

However, majority of the available literature on MHealth are based on complex interventions, combining text messaging with various forms of technology. Most of the studies in this review with the exception of the study by Dobson et al had comparatively low sample sizes. Judging by the fact that none of the data from the studies were collected beyond twelve months, makes it difficult to draw a conclusion on the long-lasting effect of the proposed intervention (MPTM) in the maintenance of glucose control. Bearing in mind that Diabetes Mellitus is a long-term illness, there is need for studies with longer duration of follow ups. Though the included studies were carried out in various continents of the world, and considering the increasing rate of network coverage in addition to mobile phone ownership. The developing and underdeveloped nations should be well considered especially in terms of creating awareness on phone-based applications. However, this study made available a beneficial overview and also described essential gaps in knowledge encountered in this field, which values more research.

Limitations of the review

This review also had limitations like lack of blinding, small sample size and short duration in some of the included studies. The small number of significant findings could be due to the small sample sizes and short durations of

the included studies. However, reports from studies suggested that lack of blinding has low chances of influencing outcomes such as haemoglobin concentration (Wood et al., 2017). The included studies did not make any note of power calculations, as such the overall generalizability of the data in relation to the populations is limited in scope. Furthermore, because the selection of studies and judgement of bias was conducted by just one reviewer, it may be seen as been prone to bias from the reviewer.

Finally, one of the major limitations of this review was that the assessment outcomes report was not done at a more general level so as to allow for major comparison across studies. This review focused solely on HbA1c, which was commonly monitored by all the included studies. This was because all other related condition with specific factors to diabetes were not completely addressed by the included studies. As a result of this, these factors were not fully discussed in this systematic review.

Conclusion

Mobile phone is considered as the most accessible in the world, while text messaging on the other hand, is also seen as the most commonly utilised means of mobile communication. Various researchers in Public Health have sought to explore and make the most out of the proposed communication modality. Text messaging interventions were designed to provide evidence that will result to enhanced health outcome and improved health behaviour. The findings from the seven studies in this review illustrated that Mobile Phone Text messaging has a significant effect on glucose control. Furthermore, factors such as Sample size, duration of intervention and level of HbA1c can influence the effectiveness of an intervention. There is need for more researches to be carried out on various mobile application and MHealth educational means, on patients with different diseases not just DM. There is also need for more researches on homogenous studies with higher sample sizes and longer duration, by so doing, there will be enhanced generalizability of findings.

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